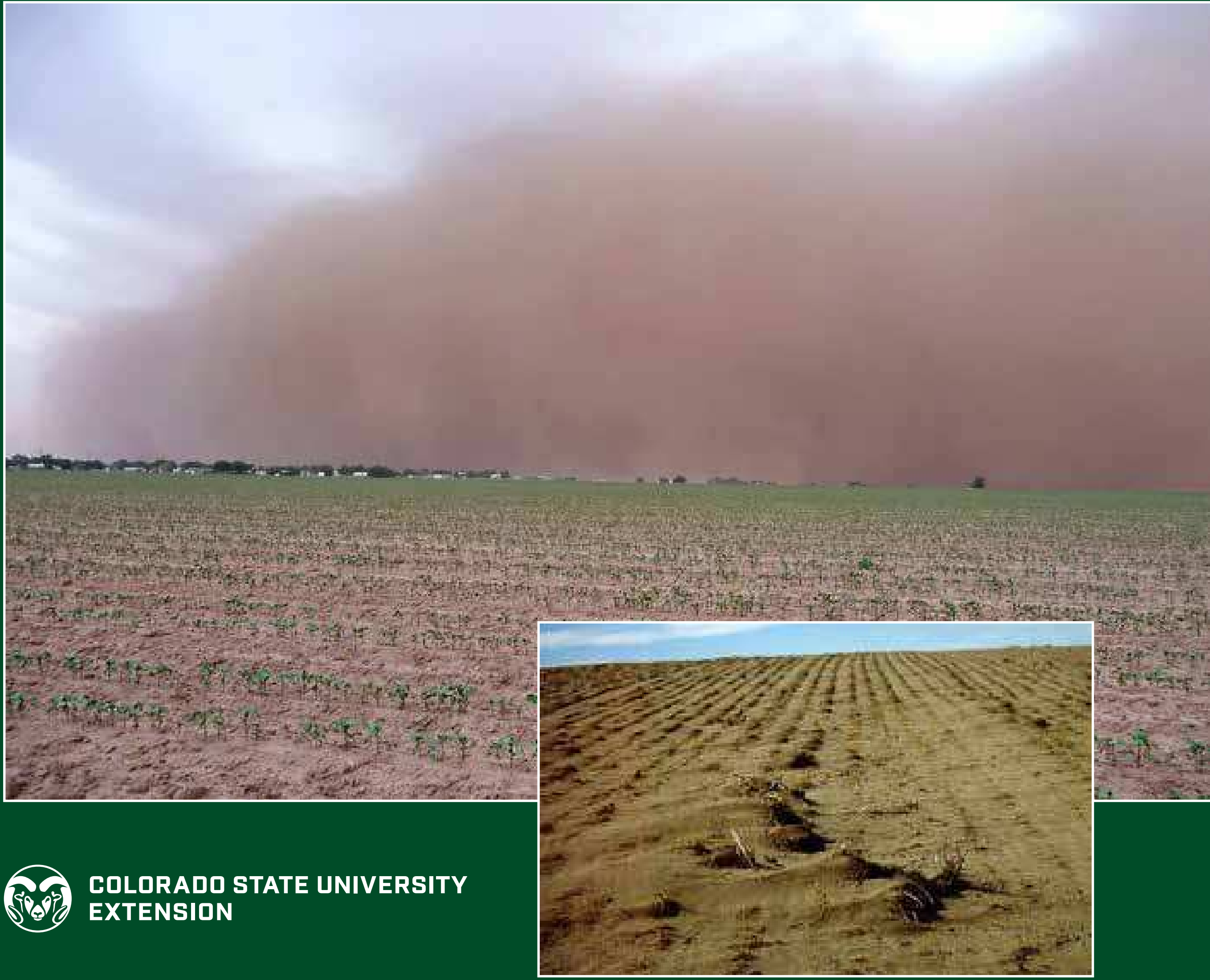
Wind Erosion Processes and Control



COLORADO STATE UNIVERSITY
EXTENSION

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Quick Facts

- Understanding the basic mechanisms of wind erosion is needed so land managers can better recognize the why, when, and where of control systems for individual situations.
- Wind interacts with the surface to cause detachment, transport, and deposition of soil particles as well as modes of transport (i.e., surface creep, saltation, and suspension). These are critical to understanding the on-site and off-site effects of wind erosion.
- Standing vegetation (alive or dead) is always more effective in slowing the wind than flat vegetation and is the most effective practice for wind erosion control.
- When vegetative cover is sparse, ridges and large soil clods are often used to control erosion. Other practices such as strip cropping, windbreaks or other barriers are also effective in some circumstances.

Introduction

Wind erosion damages the soil by physically removing the most fertile part (e.g. clays, silts, organic matter), lowering water-holding capacity, degrading soil structure, and increasing soil variability across a field, resulting in reduced crop production. It tends to remove silts and clays making the soils sandier. It also causes plant damage from abrasion, blowouts, and deposition. In addition, some soil enters the atmosphere where it obscures visibility, pollutes the air and water, causes automobile accidents, fouls machinery, and imperils animal, plant, and human health (Figure 1).

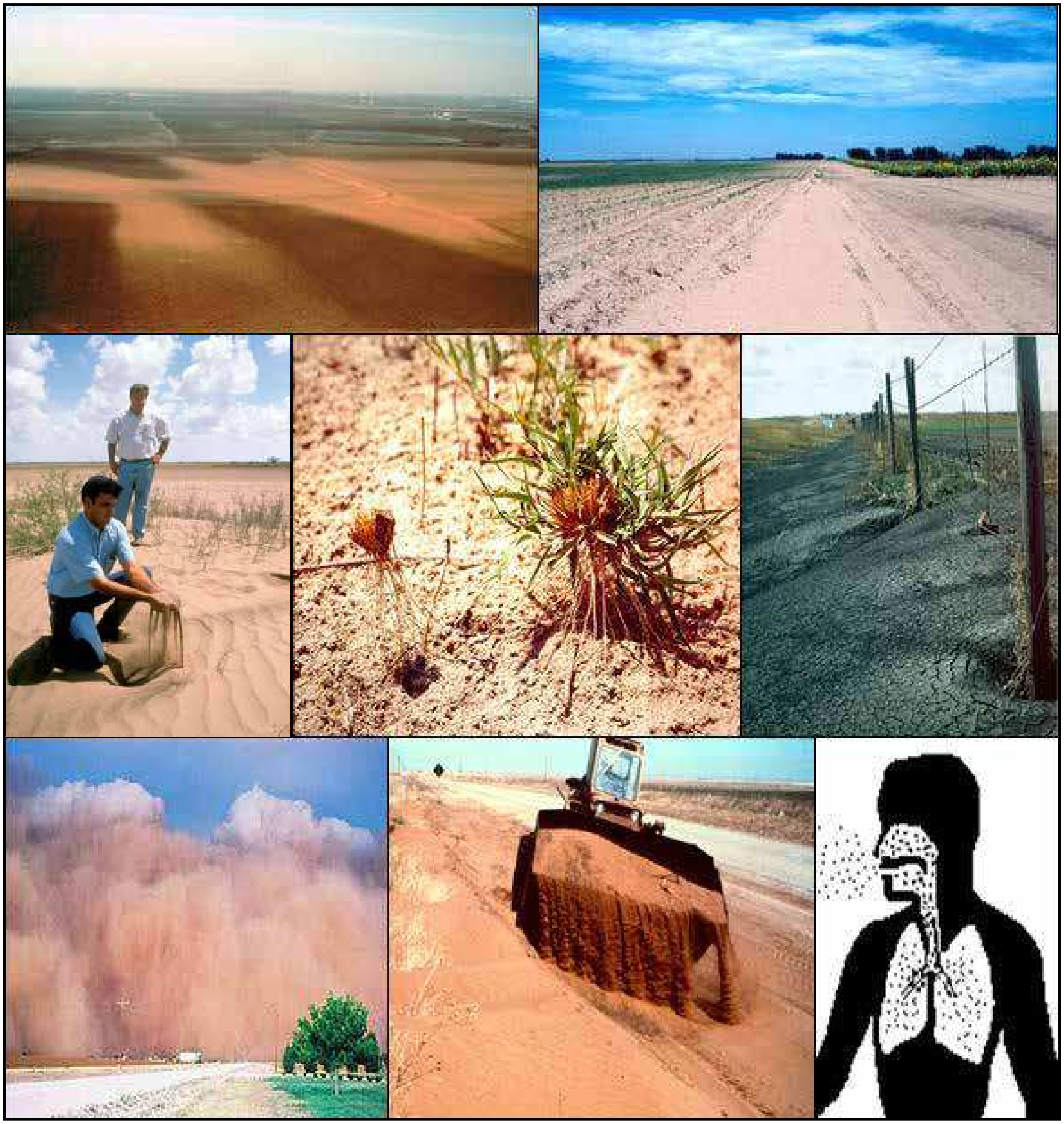

FIGURE 1. Examples of wind erosion damage including increased soil variability (upper left), plant damage (upper right), soils becoming sandier (middle left), blowouts (middle center), pollution of waterways (middle right), air pollution (lower left), traffic hazards (lower center), health effects (lower right).

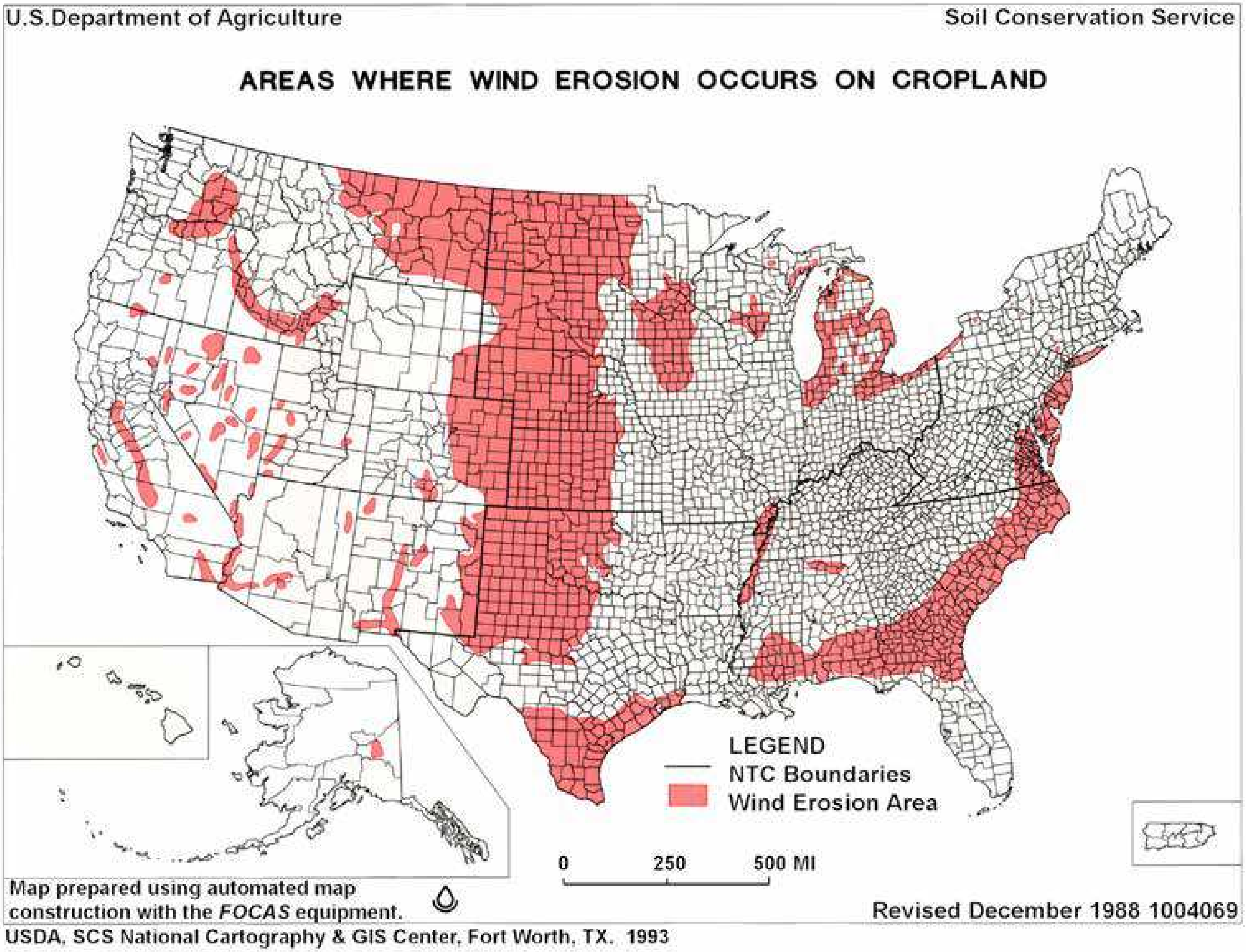

FIGURE 2. Map of areas where wind erosion is a potential problem and likely to occur on cropland in the United States. The map is based on wind regimes and inherent soil properties, therefore the map should not change appreciably over time.

On approximately 150 million acres of land in the United States, wind erosion is still a potential damaging problem, with four to five million acres suffering moderate to severe damage each year (Figure 2).

WIND EROSION PROCESSES

To effectively apply conservation systems to prevent wind driven soil loss, an understanding of the fundamental processes of wind erosion is necessary so that land managers can better recognize the why, when, and where of designing wind erosion control systems for individual situations.

Wind

We begin with the driving force of the wind, which is simply air in motion. Air has mass and when mass is in motion, it has energy. It is that energy that moves soil during wind erosion. And it is important to know that erosive wind energy increases by a factor equal to the velocity cubed, so that a small increase in wind velocity results in a large increase in erosive wind energy.

The wind high above the soil surface, unrestricted by barriers or objects, is known as “free stream” air flow and moves more or less parallel to the surface. The wind near the surface however impacts the soil and vegetation, which removes energy from the wind and slows it. So, the average forward velocity near the soil surface is lower than in the free stream. The velocity increases as the distance above the surface increases. This velocity gradient is known as a “wind velocity profile.”

The nature of the surface over which the wind is traveling can greatly influence this wind profile, as well as the wind energy near the surface (Figure 3). When the soil is rough, large clods or furrows protrude into the wind stream. While these protruding soils are exposed to stronger winds, they also absorb energy from the wind and thus protect the lower surrounding soil. This protection allows particles eroding from the upper positions to be trapped in the lower positions where they are protected from the wind. Vegetative material, either live or dead, also absorbs wind energy near the soil surface and can trap moving soil particles. Rough, cloddy, or vegetated surfaces alter the wind speed at the

soil surface and reduce the energy available to erode the soil. However, if the free stream wind speed is great enough, the wind at the surface will contain sufficient energy to initiate soil particle movement.

Prevailing Wind Erosion Direction and Critical Wind Erosion Period

When planning conservation systems, it is important to consider wind direction and windy periods throughout the year (e.g., Figure 4). It is also important to consider how vegetation may vary throughout the year relative to the windy periods. The prevailing wind erosion direction is that direction in which the greatest amount of soil is moved. This direction is primarily influenced by the duration and the velocity of wind from different directions. The effectiveness of wind barriers, strip cropping, ridges, etc. in reducing wind erosion is determined by their orientation relative to the prevailing wind erosion direction for the particular month(s) that control is desired. Table 1 lists the prevailing wind erosion direction by month for many locations in Colorado. The critical wind erosion period is that part of the year when agricultural fields are particularly vulnerable to wind erosion due to higher wind speeds than normal and low vegetative cover. In the Great Plains states, this period is typically

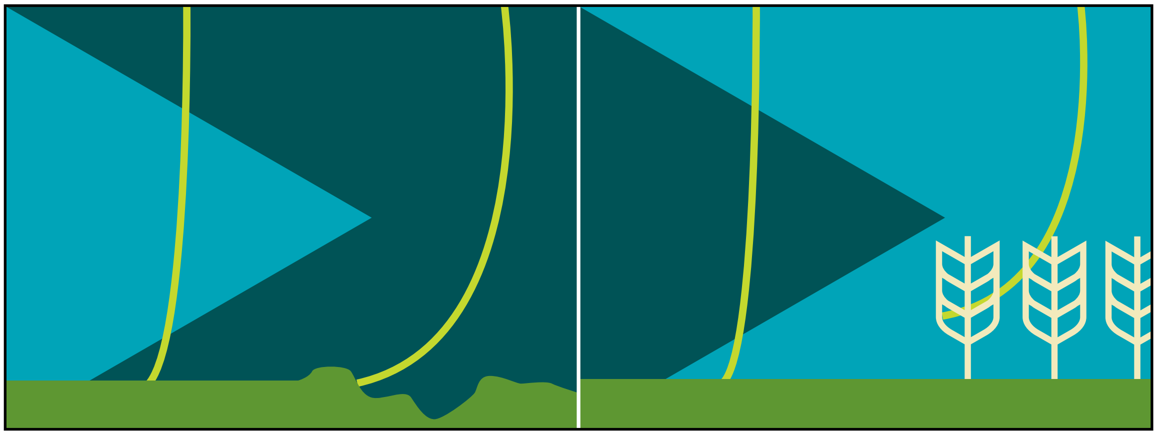

FIGURE 3. Wind velocity at the surface changes with surface configuration where longer arrows represent faster wind speeds.

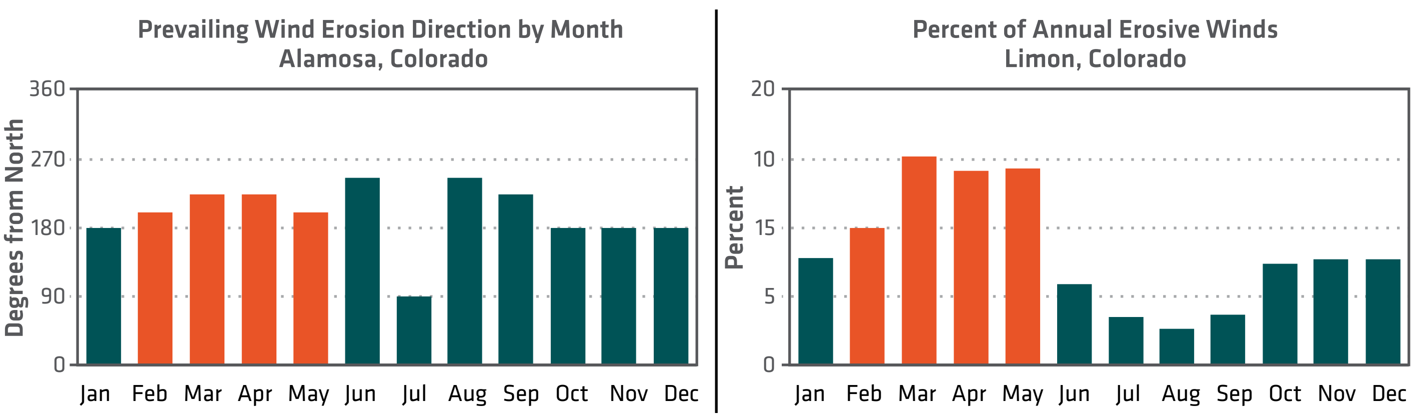

FIGURE 4. Prevailing wind erosion direction by month for Alamosa (left) where wind direction is in degrees from North (e.g., 90 degrees from north is a wind out of the east) and percent of annual erosive winds (i.e., winds > 8 m/s) by month for Limon (right) with critical wind erosion period shown in red.

	Month											
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Akron	315	338	315	338	338	338	158	158	158	338	337	315
Alamosa	180	203	225	225	203	247	90	248	225	180	180	180
Colorado Springs	0	338	0	0	0	0	0	0	0	0	0	0
Denver/Stapleton	292	292	0	158	180	180	180	180	180	315	292	293
Eagle	247	247	225	225	225	225	225	225	225	225	225	247
Grand Junction	113	135	315	180	180	135	135	135	135	113	135	135
La Junta	22	45	0	0	23	45	45	23	45	22	0	0
Pueblo	292	0	0	270	22	45	0	0	0	0	0	293
Trinidad	247	247	0	247	247	203	247	247	225	203	247	270

TABLE 1. Prevailing wind erosion direction in degrees from North for some Colorado locations.

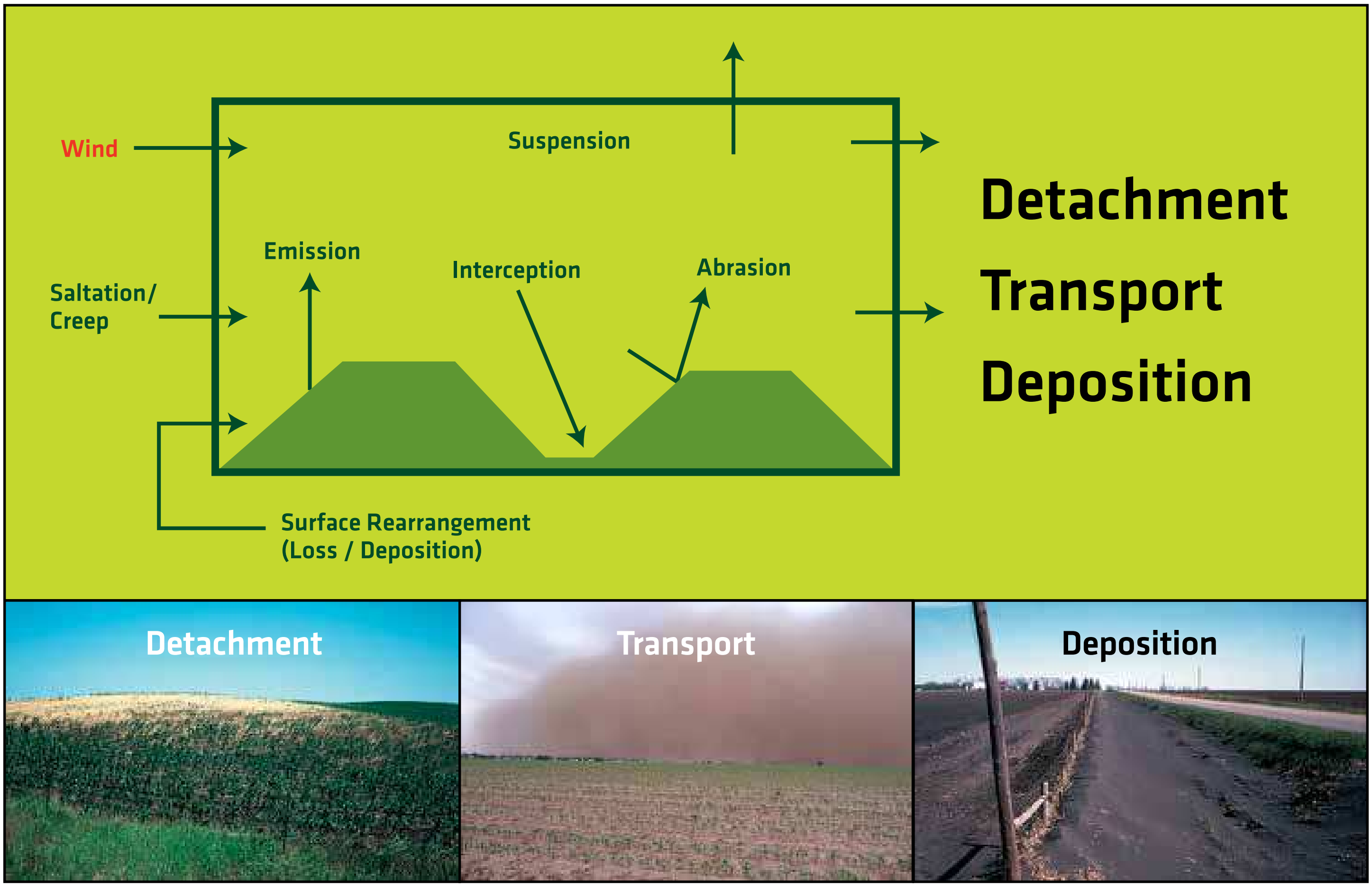

FIGURE 5. Diagram of the three primary processes of wind erosion (upper) with photo examples of each (lower).

February-May when winds are the greatest and crops are not high enough to protect the soil surface.

Phases of Particle Movement

There are three phases of particle movement - Detachment, Transport, and Deposition (Figure 5). It is important to understand each for effective erosion control.

Detachment occurs when the wind force against soil particles increases enough to overcome the force of gravity. Once detached, moving particles may collide and detach other particles. The detached soil particles are then subject to transport by the wind, either through the air or along the surface. The distance, height, and duration of transport are dependent largely on the wind speed. Eventually the wind velocity decreases and soil particles are deposited. In-field deposition typically occurs in furrows or vegetated areas. Deposition also occurs along the edge of fields in ditches, fence rows, or barriers such as windbreaks. For very fine particles, deposition may not occur until the particles have traveled hundreds or thousands of miles.

The wind speed at which particle movement is initiated is called the threshold velocity and is dependent on the state of the soil surface. A soil surface that is rough or protected with non-erodible material will require a stronger wind to initiate particle movement, than a bare, smooth surface. This means that for a given field, there is no single threshold velocity but rather a range of velocities depending on the soil surface condition, including aggregation, roughness, crop status, and moisture. Most of these properties can also change during a storm due to the erosive action.

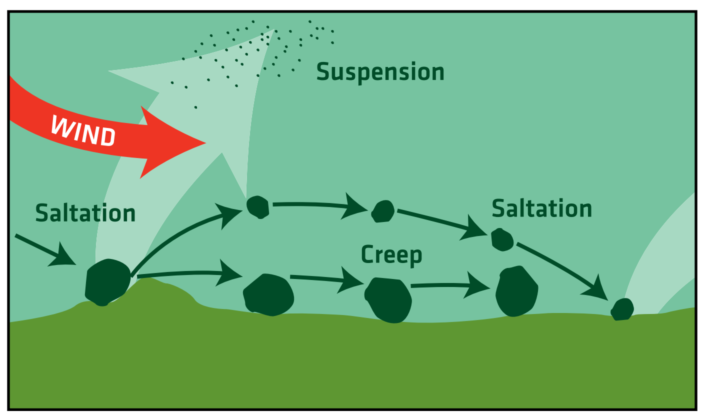

FIGURE 6. Soil particles can move by saltation, creep, and suspension.

Modes of Transport

There are three ways soil particles are moved by wind: Surface Creep, Saltation, and Suspension (Figure 6). Each has its own characteristics and effects.

Under Surface Creep, the force of the wind causes soil particles to roll along the soil surface until the wind slows, they are stopped by other particles, or they are trapped in a sheltered location, such as a furrow or a vegetated area (Figure 7). Surface creep generally involves particles approximately 1/2 to 1 millimeter

FIGURE 7. Diagram of the surface creep transport process (left) with example of its effect (right).

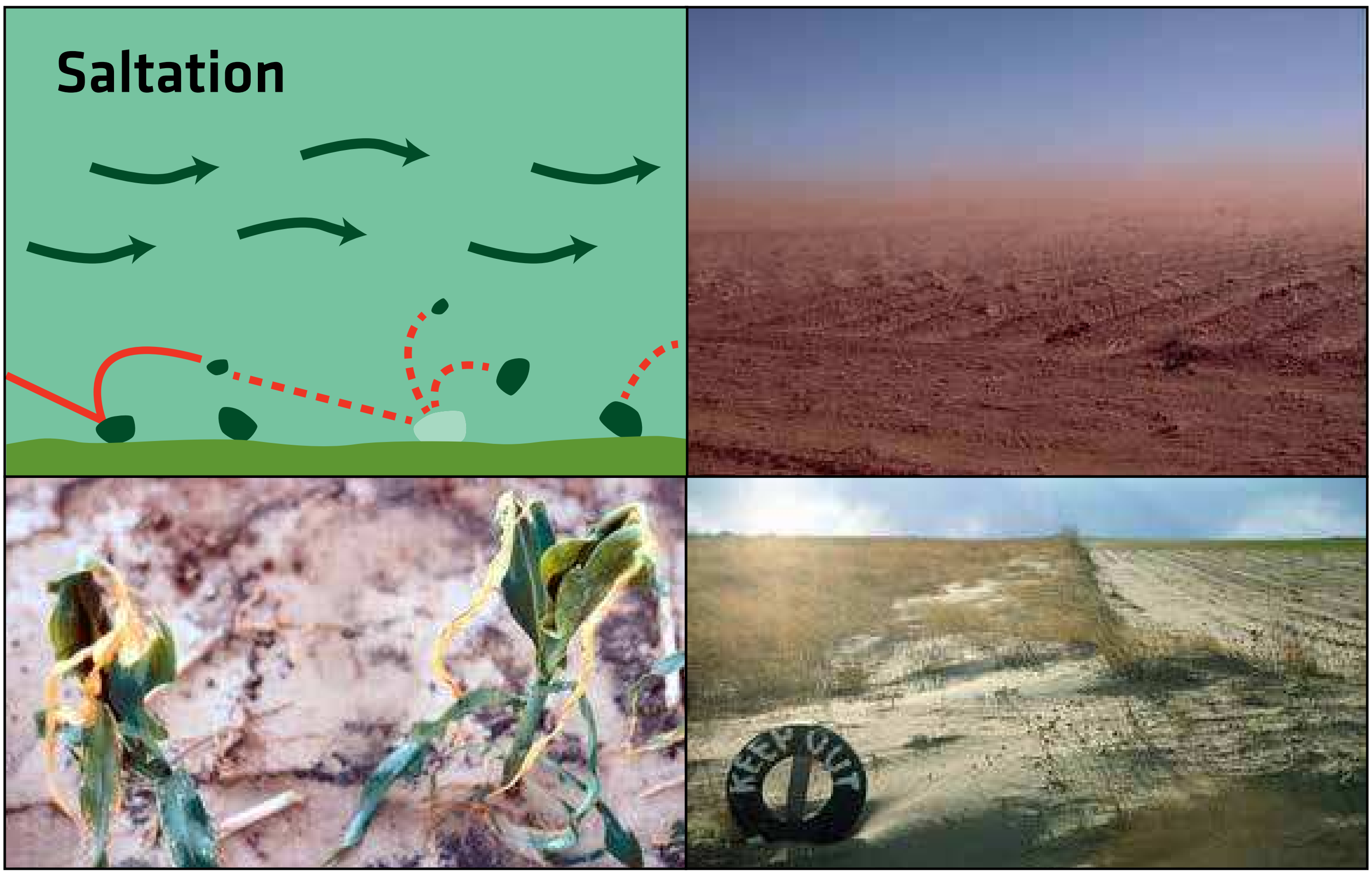

FIGURE 8. Diagram of the saltation transport process (upper left) with examples of its effects.

in size, small enough to be moved by the wind but too massive to be lifted off the surface. Surface Creep contributes to loss and deposition within a localized area.

Another mode of transport is Saltation, where under the influence of wind, still smaller particles, 1/10 to 1/2 millimeter in size, bounce or hop along the surface (Figure 8). As they bounce, they strike other particles, causing them to move. The higher the grains jump, the more energy they derive from the wind. Because of this wind-derived energy, the impact of saltating grains initiates movement of larger grains and smaller dust particles that can be suspended in the air and carried great distances. Saltating grains collide with clods and cause their breakup, reducing roughness. Saltation also damages young plants, threatening their survival. In mature plants, saltation can damage flowering parts and their fruit, reducing their marketability. Like particles under surface creep, saltating particles continue to move until the wind slows or they're trapped in sheltered areas.

FIGURE 9. Diagram of the suspension transport process (upper left) with examples of its effects.

FIGURE 10. Example of the Avalanche Effect.

Suspension refers to particles less than 1/10 of a millimeter - smaller than the diameter of a human hair - that are lifted far above the surface and carried great distances (Figure 9). Some of these form dust clouds that have been traced across continents, oceans, and around the world. Suspension can also cause visibility problems.

A small fraction of suspension particles may cause health problems when inhaled. These particles are known as PM10, which are particulate matter less than 10 microns in size or smaller.

The amount of soil that erodes as surface creep, saltation, or suspension depends on the soil type. Soils that are pure sand will move almost completely by surface creep and saltation. However, if the soil is almost pure clay with clods that break down under saltation, a high percentage of soil loss will be by suspension.

On an eroding field, the amount of soil movement will tend to increase with distance downwind due to the impact of saltating grains breaking up clods and initiating other particles to move. This increase in erosion across a field is known as the “Avalanche Effect” (Figure 10). If the field is large enough, the creep and saltation flow reaches a maximum that a wind of a particular velocity can sustain. On the other hand, the amount of suspension particles can keep increasing as they diffuse into the atmosphere.

WIND EROSION CONTROL

Many conservation practices can be implemented to control wind erosion. Conservation practices are designed to either reduce the wind force at the soil surface - or - create a soil surface more resistant to wind forces. Some practices also trap saltating particles to reduce the abrasion of soil surfaces downwind.

The USDA Natural Resources Conservation Service (NRCS) has developed an extensive list of National Conservation Practice Standards. A detailed description of each of these practices is available online at: https://www.nrcs.usda.gov. The more common control practices for wind erosion are briefly described below with their corresponding on-line NRCS control practice name. It should be noted that many practices may have been adjusted so that they apply to the local geographic conditions and one should contact the local NRCS field office for information on local practices.

Vegetation or Vegetative Residues

A conservation practice that preserves crop residue or keeps growing vegetation in the field will result in all these beneficial effects (e.g., reducing the wind force on the soil, creating a surface resistant to wind, and trapping saltating particles). This

FIGURE 11. Examples of good residue management for wind erosion control.

is the most practical way to reduce wind erosion potential. Plants and crop residues protect soil particles on the surface by absorbing a portion of the direct force of the wind, trapping moving soil particles, and enhancing soil particle cohesion. Crop rows perpendicular to the prevailing winds will control wind erosion more effectively than rows parallel with the wind. Also, standing residues are more than twice as effective as flattened residues. Other conservation practices such as windbreaks, grass barriers, strip cropping, or clod-producing tillage should be considered to supplement vegetative cover. Cropping systems which preserve surface residue are a practical approach to reduce the potential of soil erosion by wind (Figure 11). The current residue cover requirement is 30% for conservation compliance in order to receive direct payments from the NRCS programs (see NRCS practices "Residue and Tillage Management, Reduced Till" and "Residue and Tillage Management, No-Till").

Residue Management

Mulch tillage maintains crop residues on the entire soil surface year-round. It is one of the simplest systems to use in reducing wind erosion and at the same time, contributes to the control of water erosion. Excessive tillage that buries crop residues is a major cause of inadequate vegetative cover on cropland. Mulch tillage practice uses non-inversion tillage where residue is only partially incorporated using chisels, sweeps, field cultivators, or similar implements.

No-till or strip-till involves managing the amount, orientation and distribution of plant residues on the soil surface year-round, while growing crops in narrow slots or tilled strips in the field. This practice is also referred to as no-till, zero-till, slot plant, or row-till.

Ridge till manages crop residues on the soil surface year-round by growing crops on pre-formed ridges alternating with furrows which are protected by crop residue.

Seasonal residue management leaves protective residue on the soil surface during a prescribed time of year, by delaying primary tillage or seedbed preparation until immediately prior to planting.

Permanent Vegetative Cover

Maintaining permanent vegetative cover is one of the most effective ways to control wind erosion. It protects the soil from wind and water erosion forces throughout the year. Pasture and hay planting establishes native or introduced forage species for livestock grazing or feed (see NRCS practice "Conservation Cover").

Conservation cover involves establishing and maintaining permanent vegetative cover on land retired from agriculture production, such as land considered highly erodible in Conservation Reserve Program.

Critical area planting involves planting vegetation, such as trees, shrubs, vines, grasses, or legumes on highly erodible areas. This practice is used on areas that cannot be stabilized by ordinary planting techniques and may suffer severe erosion if left untreated. Critical areas include dams, levees, surface-mined land, and areas of agriculture land with severe erosion (see NRCS practice "Critical Area Planting").

The importance of vegetative cover for land protection cannot be over stressed. Permanent vegetation or crop residues are valuable resources when considering their ability to conserve soil, water, and air resources. Removing residues from fields for other uses or burning should not be done without an understanding of the erosion control consequences.

Surface Roughening and Maintaining Stable Aggregates

When vegetation is sparse as a result of drought or some cropping practices or crop types, ridges and large soil clods (or aggregates) are frequently the only means of controlling erosion on large areas. However, it should be remembered that roughness may degrade over time with the weathering effects of rainfall, freezing and thawing, as well as the wind itself. Roughening the land surface with ridges and clods reduces the wind velocity and traps drifting soils. While a cloddy soil surface will absorb more wind energy than a flat, smooth surface, a soil surface that is both ridged and cloddy will absorb even more (see NRCS practice "Surface Roughening").

FIGURE 12. Cross wind ridges can provide wind erosion control when placed perpendicular to the wind.

FIGURE 13. Clod forming tillage may provide wind erosion control where residue is lacking.

Cross wind ridges are formed by tilling or planting across the prevailing wind erosion direction (Figure 12). If erosive winds show no seasonal or annual prevailing direction, this practice has limited protective value (see NRCS practices "Cross Wind Ridges" and "Row Arrangement").

Tillage implements can form ridges and depressions that alter wind velocity. The depressions also trap saltating soil particles and stop avalanching of eroding material downwind. However, soil ridges protrude higher into the turbulent wind layer and are subject to greater wind forces. Therefore, it is important that cloddiness on top on the ridge is sufficient to withstand the added wind force, otherwise they will quickly erode and the beneficial effects will be lost. Ridging sandy soils for example, is of little value because the ridges of sand are erodible and soon leveled by the wind.

Clod forming tillage produces aggregates or clods that are large enough to resist the wind force and trap smaller moving particles (Figure 13). They are also stable enough to resist breakdown by abrasion throughout the wind erosion season.

If clods are large and stable enough, as smaller particles are removed or trapped, the surface becomes stable or "armored" against erosive action (Figure 14). The duration of protection depends on the resistance of the clods to abrasion or changes in the wind direction.

Of the factors that affect the size and stability of soil aggregates, most notable is soil texture. Sandy or coarse-textured soils lack sufficient amounts of silt and clay to bind particles together to form aggregates. Such soils form a single grain structure or weakly cemented clods, a condition that is quite

FIGURE 14. When a surface becomes armored wind erosion may temporarily be reduced.

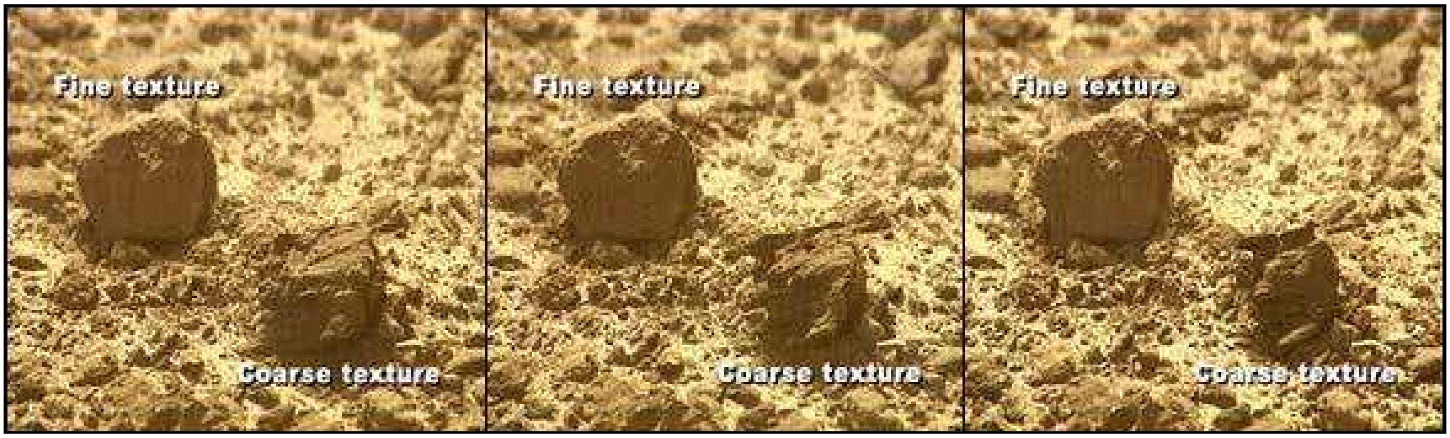

FIGURE 15. Time lapse photos of clod abrasion of fine vs. coarse textured soil, demonstrating faster erosion of the coarse textured clod.

FIGURE 16. Aggregates affected by weathering processes (left) and tillage (right).

susceptible to abrasion under wind erosion (Figure 15). Loams, silt loams, and clay loams tend to consolidate and form stable aggregates that are more resistant to erosive winds. Clays and silty clays are subject to fine granulation and more subject to erosion.

Many other factors also affect aggregate consolidation and stability including climate, moisture, compaction, organic matter, lime, microorganism activity, and other cementing materials. Any process that reduces soil consolidation also increases erodibility. The persistence of aggregates is greatly affected by the climatic process of wetting and drying, freezing and thawing, and freeze-drying, which generally disintegrate clods and increase erodibility (Figure 16).

Mechanical action, such as tillage, animal or machine traffic, and abrasion by saltating soil particles can also affect cloddiness. Tillage may either increase or decrease clods at the surface, depending on the soil condition and moisture in the tilled layer and the type and speed of the implement. Repeated tillage usually pulverizes and smoothes dry soils and increases their erodibility, especially if done with implements that have an intensive mechanical action, such as tandem disks, offset disks, or harrows.

Soil water at the time of tillage also has a decided effect on cloddiness. Research has found that different soils have differing water contents at which soil pulverization is most severe. Smaller clods are produced if the soil is either extremely dry or extremely moist than at intermediate water contents.

Cross Wind Strip Cropping

Cross wind strip cropping is the practice of growing crops in strips, arranged perpendicular to the prevailing wind erosion direction. Strips susceptible to wind erosion should alternate with strips having a cover resistant to wind erosion. This practice reduces the downwind avalanche effect by limiting the distance particles can travel before being trapped (Figure 17). As prevailing wind direction deviates from the perpendicular, correspondingly narrower strips are required (see NRCS practice “Stripcropping”).

When designing strip cropping systems, soil aggregation, machinery size, exposure to knolls, residue management, and the presence of windbreaks must all be considered. In addition, the prevailing wind erosion direction is important. On extremely erodible soils where very narrow strips are required, consideration should be given to permanent vegetation such as grass or grass-legume mixtures or even barriers between strips.

FIGURE 17. Cross wind strip cropping reduces the distance an erosive wind travels across a field.

Barriers

In contrast to methods which make the soil surface more resistant to the forces of the wind, barriers alter the effect of the wind force on the soil surface. Barriers help by reducing wind speed on the downwind side of the barrier and by trapping moving soil (Figure 18).

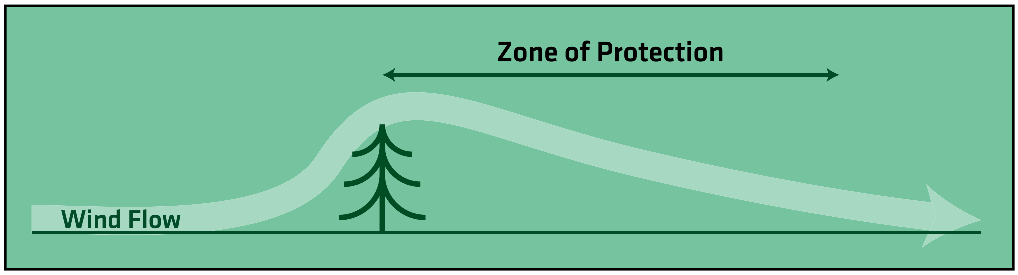

FIGURE 18. Wind barriers reduce the wind providing a zone protected from the wind.

Research has shown that barriers significantly reduce wind speed for a distance of about 10 times the height of the barrier, in effect, reducing the field length along the erosive wind direction. However, the fully protected zone of any barrier diminishes as wind velocity increases and as the wind direction deviates from perpendicular to the barrier.

There are various types of barriers used for wind erosion control. Windbreaks and shelterbelts are linear plantings of single or multiple rows of trees or shrubs, established for wind erosion control as well as snow management (Figure 20). They protect crops, shelter livestock, and provide wildlife habitat.

One advantage of windbreaks over most other types of wind erosion control is they are relatively permanent. During drought years, windbreaks may be the only effective and persistent control measure on cropland (see NRCS practices "Vegetative Barrier", "Windbreak/Shelterbelt Establishment", and "Windbreak/ Shelterbelt Renovation").

Potential negative impacts of wind breaks have also been recognized. Wind breaks require land that can otherwise be used for crops. They pose areas that are difficult to maneuver around with larger equipment. Wind breaks compete with adjacent crops for light and water. In addition, they are a potential reservoir of weeds and other pests. As with any control practice the cost and benefits of wind breaks should be evaluated by the land user.

Many of the windbreaks planted in the 1930's and 40's were wide because it was believed that wide belts were necessary to provide adequate wind reduction. The trend today is toward narrower plantings. Single-row plantings are most common in field windbreaks because they occupy the least amount of land area for the amount of protection derived from them.

The type of species planted in a windbreak has a considerable bearing on the year-round

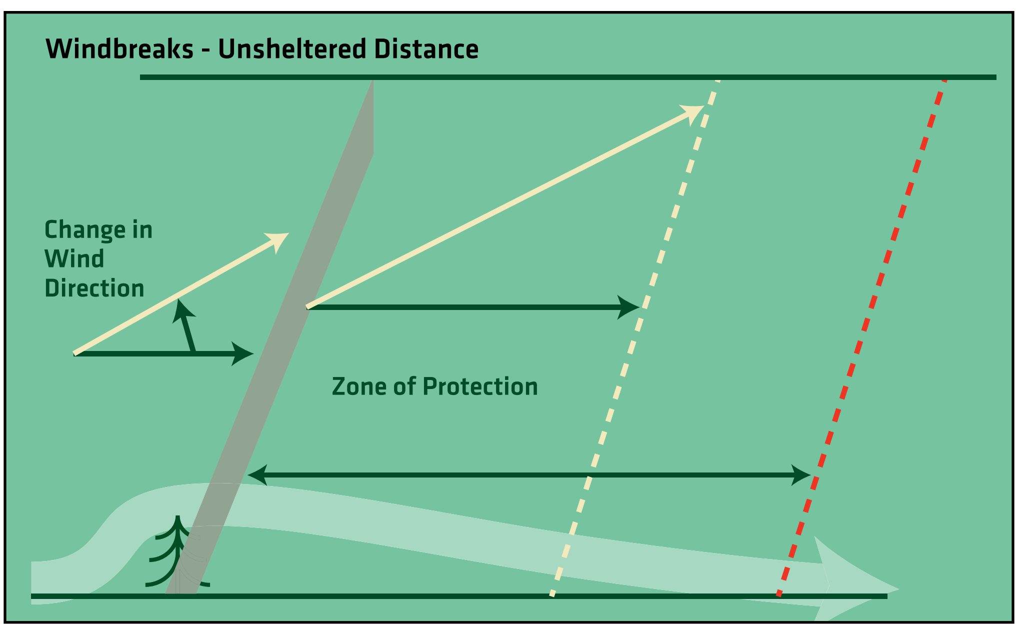

FIGURE 19. The area of protection will vary with wind direction relative to the barrier.

FIGURE 20. Barriers provide relatively permanent wind erosion control while protecting crops and livestock, changing micro climate, and affording wildlife habitat.

FIGURE 21. Cross wind trap strips are designed to trap saltating particles.

effectiveness because the amount of protection depends on the barrier shape, width, height, and porosity. The seasons also govern porosity of many species and therefore influence the effectiveness of windbreaks. During establishment of windbreaks, protection is limited and unless other erosion control measures are in place, severe damage to the plantings and the land may result.

Cross wind trap strips consist of herbaceous vegetation resistant to wind erosion, established in one or more strips, perpendicular to the prevailing wind direction (Figure 21). Since saltating particles can travel up to 15 feet, the cross wind trap strips should be at least 15 feet in width and up to 25 feet for shorter strip vegetation. The purpose of trap strips is to trap saltating particles and to provide protection from the effects of wind erosion. Trap strips, however, require frequent and expensive maintenance (see NRCS practice “Cross Wind Trap Strips”).

Herbaceous wind barriers are tall, non-woody vegetative barriers, established in 1-2 row narrow strips across the prevailing wind direction (Figure 22). These are primarily used on soils where stubble mulching and strip cropping do not adequately control wind erosion. Perennial barriers are often the only control alternative here, short of retiring the land to permanent grass (see NRCS practice “Herbaceous Wind Barriers”).

Perennial grass barriers work well for wind erosion control, as well as trapping snow and reducing evaporation on dry-land cropping areas (Figure 23). Other advantages of these types of barriers are ease of establishment and low cost.

FIGURE 22. Herbaceous wind barriers are an alternative to other control methods that do not adequately control wind erosion or are otherwise not appropriate for a particular field.

FIGURE 23. Perennial grass barriers are an easy, low cost control that also trap snow and reduce evapotranspiration.

FIGURE 24. Annual crop barriers can also provide protection on a temporary (seasonal) basis.

Annual crops can also be used as herbaceous wind barriers, so one crop provides protection for another crop (Figure 24). Sundangrass, flax, grain and forage sorghum, and broomcorn are examples of crop barriers that can provide adequate protection from wind erosion if spaced sufficiently close.

Artificial barriers such as snow fences, board walls, bamboo and willow fences, earthen banks, hand-inserted straw rows, and rock walls have been used for wind erosion control, but only on a very limited basis (Figure 25). There is usually a very high cost in material or labor to construct these barriers and their use is generally restricted to high-value crops. They can also be used in sand dune areas to aid in the initial stabilization phase, while grass and trees are being established.

Emergency Wind Erosion Control

The practices discussed so far are known to substantially reduce wind erosion. However, if a soil begins to blow, it should be controlled as soon as possible because serious damage to seedlings or soil can occur in minutes. Often, wind erosion will

FIGURE 25. Artificial barriers are of limited use often as an emergency control.

FIGURE 26. Adding crop residue is an option to reduce wind erosion.

start in a small area of a field where soil texture, aggregation, or vegetation conditions are more vulnerable to wind forces. Highly erodible areas also include knolls, wheel traffic areas, and blowouts. If these areas are allowed to erode, the saltating material can cause other areas of the field to erode until eventually, the entire surface is blowing. These vulnerable areas or "hot spots" will be the areas that need emergency control first. Watching the field over the years and within a season can tell you where such areas are within a field. Anticipating erosion on these spots when high winds are forecast is a valuable tool for fighting erosion. It is easier to control erosion before it starts than to stop it after.

Addition of crop residue to the surface reduces wind velocity and traps moving soil particles (Figure 26). Almost any kind of residue, such as hay, straw, or corn stalks can be used. Approximately 2000 to 4000 pounds of residue per acre is required to control erosion in areas where erosion has already begun.

Residue can be distributed with a manure spreader, or even by hand if the area is small. This method is not normally used in entire fields or with row crops, but is most practical as an emergency treatment. A rotary hoe or mulch treader helps spread the residue uniformly.

Normally the residue must be anchored in place with a stubble puncher or a disk with gangs set at a minimum angle and shallow depth (Figure 27). Large stemmed residues such as corn stalks are effective and might not require anchoring. The direction of operation for residue distribution and anchoring should be perpendicular to the direction of the wind (see NRCS practice "Mulching").

Livestock manure acts like crop residue or large clods and can reduce wind erosion by slowing the wind velocity at the soil surface and by trapping soil particles (Figure 28 – left). It can be effective in growing wheat, fallow fields, and row crops. Typically 6 to 8 tons of manure per acre effectively controls wind erosion on vulnerable spots. Manure should have sufficient moisture and size so it will not be dislodged or broken into smaller particles. Precaution should be taken when storing and applying manure, so it does not contaminate water sources.

Erosion control with irrigation is generally impractical and wastes water because the surface tends to dry rapidly under high wind conditions (Figure 28 – right). The impact of large water

droplets from sprinklers also deteriorates soil structure, smoothes the soil surface, and produces loose particles which encourage wind erosion once the surface has dried. However, if a high value cash crop is being severely damaged by wind erosion, irrigation might be a practical solution if enough water can be applied to keep the surface sufficiently moist.

Emergency tillage is tillage performed on an actively blowing field to provide a rough, ridged, cloddy surface that reduces wind velocity and helps trap windblown soil particles (Figure 29). It should only be used when other efforts have failed. Emergency tillage is only a temporary measure because clods can disintegrate rapidly under saltating conditions and a change in wind direction can occur.

An implement used for emergency wind erosion control should gently lift the soil, creating as many and large stable clods as possible (Figure 30). Disks and harrow-type implements with several ranks of closely spaced tines that pulverize the soil should not be used. Implements such as listers, chisels, shovels, and sandfighters do a good job of roughening the soil surface and creating clods. Listers and narrow chisels are the most effective for emergency tillage. Listers provide a high degree of roughness on extremely sandy soils, where clods can be produced only by deep tillage. Chisels are more widely used on moist or heavy soils because they provide good ridges and clods, require less power, and destroy less crop or residue than listers.

Some operators prefer a soil ripper to bring up large, dry clods when subsurface soil is dry. Where subsoil high in clay exists under a sandy surface, deep plowing the entire field is sometimes used to bring clayey stable clods to the surface. If the clods brought to the surface are numerous and stable, deep plowing is only necessary once every several years. Another method is to time tillage when the top of the soil is frozen, to bring up frozen clods.

Close spacing with any implement will create a rougher surface than a wide spacing. However, if a crop is involved, such as winter wheat, and there is a possibility of saving part of it, then a wide spacing of 4 to 5 feet provide sufficient roughness for some control and at the same time permit most of the crop to survive.

Tilling strips across the field perpendicular to the expected wind direction is most effective. The success of emergency strip tillage is highly dependent on climatic, soil, and cover condition. If strips are used, they should be as narrow as practical and cover 50 percent of the eroding part of the field. Narrow chisel spacing

FIGURE 27. A mulch treader (left) is useful for evenly distributing added residues and should be anchored by inserting the residues (right).

FIGURE 28. Adding manure on the surface (left) and wetting the surface with irrigation (right) are additional emergency wind erosion control methods.

of 20-24 inches is needed for the strip. If 50 percent coverage does not stop erosion, the omitted strips can be emergency tilled to make full coverage.

Temporary, artificial wind barriers or roughness elements can be used for emergency control if the eroding area is relatively small (Figure 31). For example, a stock watering area or knoll can be protected by board fences, snow fences, hay bales or anything that will slow the wind at the surface. Protection can be expected for a downwind distance approximately 10-15 times the height of the barrier.

Soil stabilizers are soil additives or spray-on-adhesives which bind soil particles together (Figure 32). Example soil stabilizers commonly used include hydrocarbon emulsions, synthetic polymeric emulsions, or even plant processing byproducts or extracts. They are generally expensive, temporary, and used only for high value cash crops, such as vegetables. Several materials of petroleum or organic origin are available. They are not compatible with all soils and often made ineffective by subsequent rainfall, cultivation, or abrasion from untreated areas.

FIGURE 29. Emergency tillage provides a rough, cloddy surface to reduce the wind velocity at the soil surface and provide quick but temporary control.

FIGURE 30. Any tillage that increases roughness or clod size will reduce wind erosion but may be temporary as clods and roughness degrade.

Wind Erosion Models

Wind erosion simulation models can be useful for the design of wind erosion control systems (Figure 33). By observing how soil loss is affected by simulated weather, field conditions, and management operations, alternate management systems can be developed to control soil loss.

The Wind Erosion Prediction System or WEPS is a process-based, daily time-step, computer-simulation model. WEPS was developed by USDA-Agricultural Research Service (ARS) to simulate wind erosion. By varying management inputs, the user can compare various alternatives to develop the best strategies for wind erosion control for a particular location, field shape, and soil type. The user manual available with the WEPS model provides more information on its use in designing management systems for wind erosion control. The WEPS model can be downloaded from the ARS at: https://www.ars.usda.gov/research/software/.

FIGURE 31. Artificial barriers such as hay bales (left) or objects to create roughness (right) are temporary controls.

FIGURE 32. Soil stabilizers bind particles together to make them less erodible.

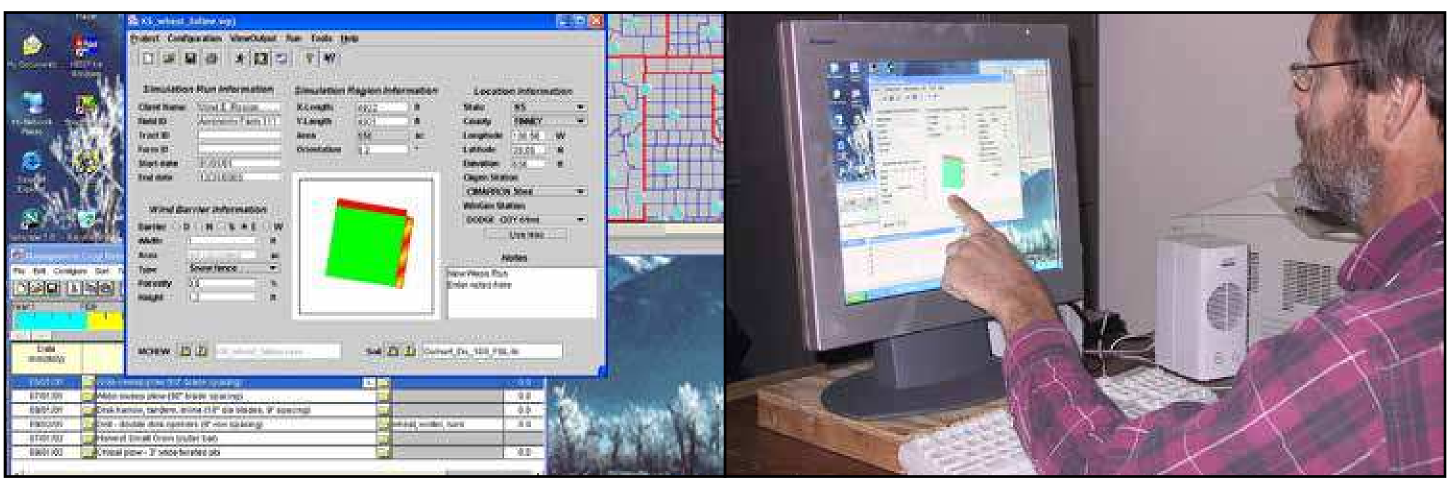

FIGURE 33. Wind erosion simulation models allow a land manager to develop alternative conservation plans to see the effects of management scenarios on wind erosion.

FIGURE 34. Various research activities continue to better understand the processes, causes, and control of wind erosion.

Research

The USDA-Agricultural Research Service, with support from the Natural Resources Conservation Service, continues to research processes, causes, and control of soil erosion by wind (Figure 34). Through this research it is hoped that even better control strategies will be developed for current and future land managers.

SUMMARY

A sound understanding of the processes that cause wind erosion is the key in developing effective control strategies. Although conservation practices can be successful in controlling erosion, droughts can cause a shortage of residue, and erosive winds will not always blow in a prevailing direction. Thus, land managers must be ever vigilant and combinations of practices may need to be considered when planning a wind erosion control system.

WIND EROSION RESOURCES

General Wind Erosion Questions

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Wind Erosion Prediction System

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NRCS National Conservation Practice Standards and Work Sheets

https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/

NRCS Field Office Technical Guide

https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg/